THE CHEMICAL AND MICROBIOLOGICAL QUALITY OF THE DANUBE WATER UNDER ICE COVER IN THE EXTREMELY COLD WINTER OF 1962/1963 AS RELATED TO THE WATER SUPPLY OF BUDAPEST

(Danubialia Hungarica, XXVI.)

by

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Received on October 10th, 1963

The amelioration of the quality of drinking water is being a constant duty of the Metropolitan Water Works of Budapest the Water Works had to face already in previous years the various problems of water quality.

Over a long period the questions connected with the ironand manganese contents of the water were the chief problems. The elimination of iron content is, by the way, a serious economical subject of our deep bored wells for the value of the tubes built-in amounts yearly to about 60 million Forint. (Gabos 1961.)

Since the beginning of the sixtieth the old coastal filtration water supply establishment of antiquated capacity did no more cover the requirements of enlarged Budapest. Frequently water supply difficulties occurred. To eliminate the water deficiency, the water of the Danube was also artificially and directly cleaned. Several papers report on the significance and role of the superficial water elevation works in the water supply of Budapest. We refer to the studies of Abos (1961), Alföldy (1961, 1962), Lindenmayer (1961), Pálhidy (1962), Varró (1961), etc.

The water deficiency can be practically liquidated by the application of level works. By the establishment of these, however, new problems arose, bearing on the quality of drinking water. New taste and smell characteristics appeared whose study requires detailed biological and chemical analyses. The improvement of water necessitates a long systematic research work.

The source of the drinking- and industrial water supply of the metropolis is the Danube.

From this it is obvious that the continuous temporary alterations of the Danube water due to natural, chemical, bacteriological, biological, sedimentary,

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etc. factors influence the technique of the water production and thus the quality of drinking water itself.

On account of the possible deterioration in the quality of drinking water it is necessary to acquaint ourselves with the Danube as the basis of our water supply from all aspects.

Our examinations conducted at an axceedingly low water level in autumn 1961 showed that the biological-chemical alterations of the Danube water produce a powerful effect on the process of artificial water cleaning. It is to be emphasized that in the case of natural sieving of the water of the coastal wells a less distinct quality change takes place. (Szemes, Bozzay, Bánáti 1963*a*, *b*). That the transformation of the rivers into drinking water or at least a better industrial water comprises a diversified and very complicated task, is evidenced by the analyses carried out at the central station for the supply of water of the town Pécs. (Szabó, Hankó 1963). In the production of drinking water troubles may be caused by the changes of the raw Danube water induced by different seasons, ebbs and tides, etc.

The sequence of these repeated changes was not identical either.

The extremely severe winter of the year 1962/1963 directed our attention to the circumstance that in the Danube water in the months of January, February and March biological and chemical quality changes of such a degree may occur which are unfavourable to the superficial water production, even to that of the coastal filtration wells. Meteorological records prove that the winter of 1962/1963 belonged to the severest ones even for centuries past. The Danube and its tributaries were covered with massive sheets of ice and thick snow layer.

The degree of ice cover of the Danube may be very variable depending on the weather (Pécsi 1958, Tőry 1952). On the average the Danube is covered with ice in every second year and this period lasts as a rule only for a few weeks. This was the case also recently in the winter of 1961/1962. Under such usual freezing conditions the superficial water works produce drinking water of average quality without difficulty.

In the exceptional cold winter of 1963 the Danube even in March was covered partly by immobile, uniform ice floe. At intense formation of sludgy- and bottom ice, the racks of the water elevating work became closed .

Abos (1963) reports that of the methods aiming to eliminate the sludgy- and bottom ice he experimented with the heating of the racks and with the method of blowing air under the racks, but he did not meet with satisfactory success. Up to now the method of destroying ice by fire and by manual work still proved to be the most suitable. (Protocol. Contrib. Metr. Wat. 1963. III. 28–29.)

The great drifting and the breaking up of the ice cover on the Danube began in the second half of March. The thickness of some of the ice plates cast ashore by the waterstream at Alsógöd and Megyer amounted to 1 metre. But not the racks alone have been charged by the enormous icing with technical disturbances.

This ice cover and the thick snow layer above it altered in many respects the life of the river and influenced the quality of the drinking water too. It is not within our reach to make comparisons as subglacial biological researches

Fig. 1 – 2. Ice plates of 0,5 – 0,6 metre thickness on the shore of Alsógöd at the start of the Danube drifting. Photo: Bánáti

have previously not been conducted in the Hungarian Danube zone. The Cryptogams of the icy water of the backwater of the Austrian Danube tributaries were investigated by Schiller (1926). Recently the Russian worker Vladimirova (1961) reports on the algological conditions of the Danube under ice cover, but only for an ice thickness of 30 cm. As the investigation of the Danube began under an international organization scheme by all states along the Danube the better knowledge of the living world of the icy water is to be expected. (Dudich 1960, Liepolt 1959).

The light conditions of the snow covered ice-bound lake Balaton was studied by Entz and Fillinger (1962) and the aquatic life reflecting in the ice of the same lake was searched by Entz and Lukacsovics (1957). Investigation of the rivers under ice cover is insufficient while examination of the lakes is considerably advanced. (Schüssler 1963).

To aquaint ourselves with the bacteriological and chemical characteristics of the snow-covered ice-bound Danube we took day by day samples in the first quarter of the year 1963. Results are recorded in weekly averages and condensed in tables. The other microorganisms were studied by us three times in January, four times in February and again on three occasions in March. We took the last sample collection on 19th March 1963. The place of the collection was the opening of elevating bolt on the island of the great superficial water work. We collected for the qualitative detailed analyses 30 l-sedimented, for the quantitative determinations, drawn samples of 100 ml.

Summary of the results

In the winter of 1962/1963 the Danube and its tributaries were massively ice bound and covered for a long time with a thick snow layer. This caused manifold alterations in the life of the river.

1. It hindered the natural ventilation of the water, namely the mixing of the same with air. The uptake of oxygen from the air was considerably limited which in the course of time resulted in the reduction of the dissolved oxygen content. The minimum was 46 per cent was measured in February. The Hydrological Research Institute observed a minimum of 36,1 per cent in February.

2. The thick ice cover impeded the penetration of the necessary sunlight into the water. The number of assimilating vegetable microorganisms became exceedingly low. The extreme reduction of assimilation also contributed to the low value of the oxygen content of the water.

3. The ice covering made the evanescence of the decomposition products of the organic materials of the water impossible. Due to the higher solubility as a result of the lower temperature the accumulation of these detrimental gaseous substances in the water considerably increased.

4. It is to be pointed out that the oxidable organic content of the water has attained in the winter generally a high value. This fact too refers — together with the chloride ion — to the increase of dissolved contamination of the water.

5. The combined effect of the long lasting low temperature, light deficiency the continously increasing relative waste water content and the lack of ven-

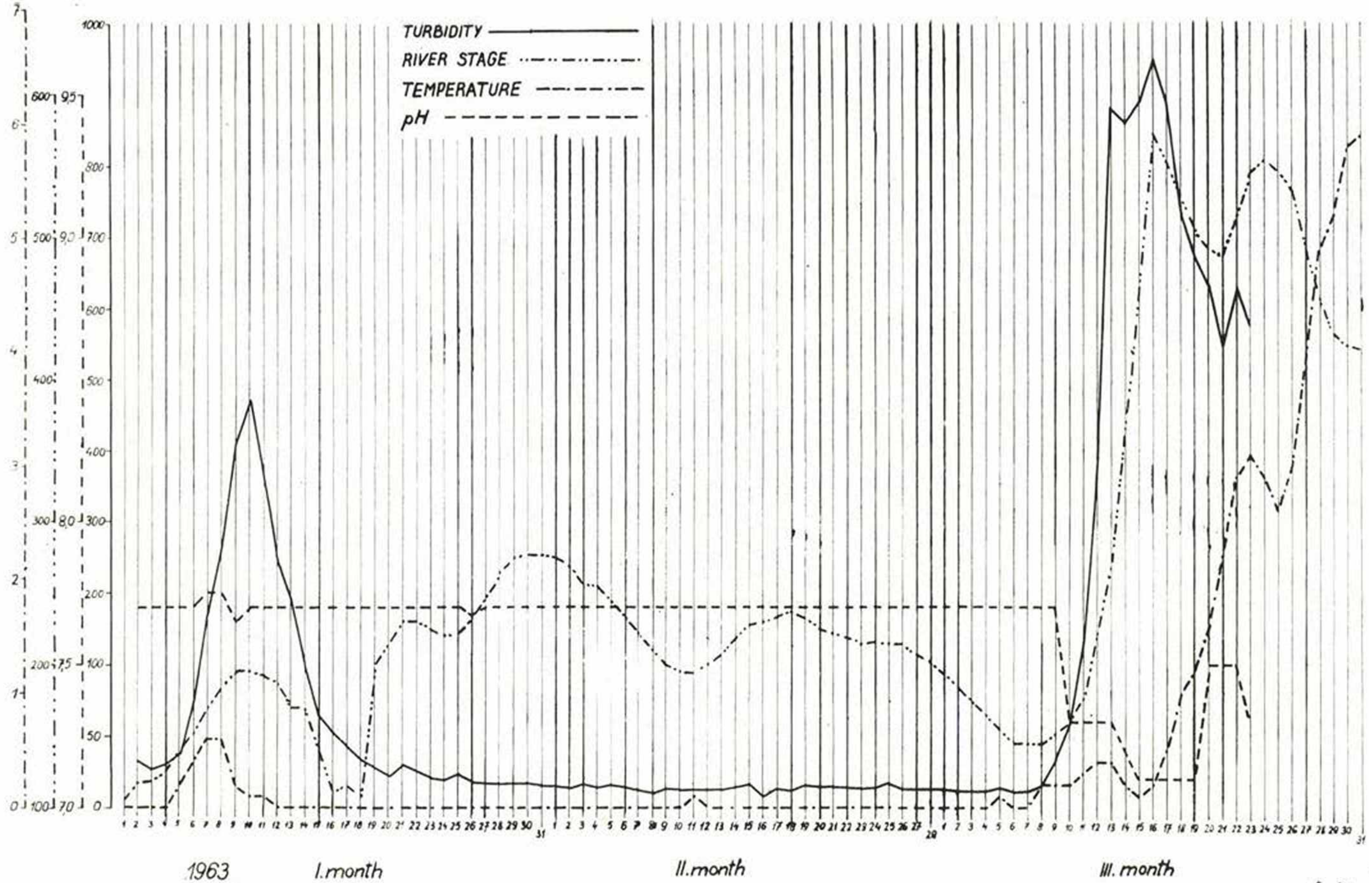

Fig. 3. Connections between water level, turbidity, temperature and pH value of the Danube

tilation hindered the chemical processes which should promote the self cleaning of the water. The mineralization of dirty waters flowing into the Danube could not proceed in the desirable manner.

6. In the water of the Danube a fusty, unpleasant chemical taste and smell was perceptible. In our drinking water supply this appeared first in the artificially cleaned waters, but later it has been found also in those of the coastal filtration wells.

The taste- and smell troubles ceased only after the drawing off of the ice cover together with the rising of water level. The usual chemical and microbiological state of the Danube water returned after the breaking up of the ice cover in the second half of March.

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When for the drinking water supply of Budapest the question of the superficial water works and their realization arose, a number of data were available on the chemical-bacteriological quality of the Danube water. The laboratories of the Metropolitan Water Works conducted for more than five years systematic analyses of the Danube water. As a result of this research work it could be stated that according to the preliminary chemical, biological and bacteriological examinations of the samples taken from the Danube water on the northern boundary of the metropolis the water of this great Central-European river was comparatively clean and represented a superficial water free from industrial contaminations. Papp (1961) studied the Danube for several decades at the Hydrological Department of the Hungarian Institute for Hygiene, he and his co-workers used to collect the water samples at 29 places and the number of their water analyses exceeds six thousand. According to this author: "It is characteristic for the bacteriological pureness of some Danube zones that the coli number exhibits at several localities 0,2 value i. e. it corresponds to the adequate quality of the drinking water. These localities were the Danube branch at Moson, Dunaremete, Gönyü, Esztergom, Nagymaros, Dömsöd and Mohács". The Scientific Research Institute for Water Economy collected between 1958—1961 more than one thousand water samples and determined 27 thousand components. Pásztó (1961) in this connection referring to the water supply, states as a significant result that: "According to our examinations one of the qualitatively purest water zones of the Hungarian Danube route is to be found in Budapest and particularly in the inner city".

More recently T. Dvihally (1963) contributed data to the evaluation of the chemical realtions of the Danube water making use of the mathematical statistical method. She refers in her study to the fact that the quantity of the solved salts in the Danube water is the highest in winter, chiefly in the period when the river is ice bound for a long time. To the chemical-biological qualification of our waters the mathematical method can indicate in the future valuable points of views and we are to avail ourselves of them for our drinking water production. Varró (1961) too states that the water of the Danube meets the requirements and adequately conditioned drinking water can be gained from it by the application of suitable technology. His statement concerns the towns Budapest and Mohács.

The contamination and the organic sediments of the Danube water under ice cover. The water of the Danube when covered with ice was generally free from rough sediments, almost clean when examined with the naked eye. In the middle of March the samples contained much mud- and sand granules.

The microscopic views of the seemingly clear samples also showed different elements of organic and decaying microorganisms. The number of the uninjured and healthy individuals is extremely few. We observed many necrotic specimens.

The raw Danube water contained a certain quantity of organic waste: vegetable fibres, starch granules, epidermal fragments, epithelium elements, pieces of muscles, etc. Among normal winter conditions, when the Danube has only been covered for short periods with ice, we never observed similar wholesale accumulation of the waste substances. Our statement is based on several years' examinations.

In the Danube when ice-free and/or covered with ice only for a limited period the contaminating organic materials decompose more rapidly. We point to the data gained from our chemical analyses which showed especially in the oxygen saturation differences from the normal chemical conditions. The quantity of the dissolved oxygen was substantially below the average level. The Research Institute for Water Resources (RIWR) and the laboratory of the Metropolitan Water Works observed simultaneously this striking phenomenon. This deficiency of oxygen detrimentally influences the formation and development of the biocenoses.

The life processes disturbed by the scarcity of light and oxygen were probably still aggravated in their disadvantageous effects by the fact that the various factories and works might have poured more freely their waste waters into the ice covered river than at other times.

Besides unfavourable microbiological conditions owing to the light- and oxygen deficiency, the Danube was comparatively overcharged with the sewage of the households as the dilution possibility of the streaming in putrid waters had been checked at the lower water capacity. In the following some data of the measurements of the water capacity in cu. m/sec. are given together with the percentages of the O_2 saturation according to the RIWR while those of the laboratory of the Metropolitan Water Works are condensed in Table 1.

Date 1963.	*Water capacity cu. m/sec.*	*Percentage of the O_2 saturation*
I. 7.	1200	83,0
II. 6.	647	44,2
,, 11.	623	46,3
,, 18.	752	50,3
,, 20.	716	36,1
III. 4.	539	51,0
,, 11.	597	64,4
,, 18.	4290	70,6
,, 20.	3890	75,0
,, 22.	4140	74,6

Table 1.

The chemical and microbiological examinations of the Danube water in the first quarter of the year 1963.

The weekly average data of the daily analyses

Consecutive numbers of the calendar weeks	Chemical analyses											Microbiological examinations: Bacteriological					Microbiological examinations: Schizomyc. Mycophyta Algae	
	Total solid substances	Chloride (Cl^-) mg/1	Decr. of O_2 with $KMnO_4$ (O_2) mg/1.	Percentage of dissolved O_2	N_2O_5 mg/1	Basicity	Variable hardness German hd.	Total hardness German hd.	Remainder hardness German hd.	Calcium-ion mg/1	Magnesium-ion mg/1	Temperature in C degrees	Clostridium in 40 ml	Coli number in 1 ml	Germ number on 20 C degree	Germ number on 37 C degree	Ind./ml	Taxon number
1	–	22,0	7,0	–	3,0	3,5	9,8	13,0	3,2				50	51	800	200	24	31
2	–	19,2	7,4	–	3,5	3,0	8,4	10,7	1,7	60,8	20,7		76	100	1000	120	10	24
3	305,0	21,8	6,6	87,0	3,5	3,3	9,2	12,6	2,4	59,6	39,1	0	64	92	1200	180		
4	331,0	23,0	7,3	81,9	4,3	3,6	10,1	13,2	3,1	58,6	33,2	0	66	120	960	230	9	19
5	305,0	24,1	11,2	65,2	4,2	3,6	10,1	13,6	3,5	64,3	22,6	0	50	58	1400	220	3	22
6	354,5	23,6	12,0	58,8	4,8	3,6	10,1	15,1	4,9	71,4	26,1	0	65	37	1500	280	5	11
7	405,0	24,0	8,9	56,5	3,3	3,7	10,4	16,2	5,7	–	–	1,5	72	120	2000	220	12	31
8	311,0	25,3	10,5	59,9	3,6	3,5	9,8	15,7	5,9	65,8	27,8	1	84	83	900	100	5	21
9	330,0	26,5	7,4	62,8	3,5	3,4	9,5	14,4	4,9	64,2	26,1	0	65	52	1000	240	9	5
10	355,0	25,0	7,6	61,9	4,2	3,7	10,4	14,7	4,3	–	–	1	69	45	6500	1870	23	21
11	340,0	15,0	7,3	78,9	4,3	2,5	7,0	10,3	3,2	35,7	10,2	0	160	92	9300	2000	96	32
12	251,0	12,8	8,4	89,7	4,3	2,3	6,4	9,2	2,8	42,9	15,2	2,3	120	110	4800	570		

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The above data show the relatively lower water capacities especially in February and in the first half of March. This circumstance essentially favoured the increase of putridity.

On the vegetal microorganisms of the icy Danube water.

Though a number of papers were published dealing with the microscopic plants and animals of the Danube yet they are not concerned with its subglacial living world.

In the composition of the microbiol world of the Danube water covered with ice the main feature is the fact that the various protozoa which we found in other times generally in a scarce number, significantly increased thus for instance *Glaucoma* sp., *Colpidium* sp. and *Paramaecium* sp. Quite similarly there several species of bacteria and fungi appeared to a relative larger number.

The analysis of microvegetation. Here we have taken into consideration merely those bacteria *(Schizomycophyta)* and fungi *(Mycophyta)* which can be identified without isolation methods. The results of the examination of the cultivations are reported separately in Table 1. which includes the bacteriological and chemical data.

Almost in each of the phytoplancton samples there occurred the iron bacterium *Leptothrix ochracea*. Its number is ascending from January towards March and the maximum is reached at a rate of 13 ind./ml directly before the start of the motion of the ice. Also *Beggiatoa alba* is of more frequent occurrence, nevertheless its number never exceeded the ratio of 2 to 3 ind./ml. On the whole *Cladothrix dichotoma* accurs to a similar extent. The latter reached on 19th March the value 4 ind./ml. *Gallionella ferruginea*, *Thiothrix nivea* and *Peloglea bacillifera* are sporadical. A few specimens of *Leptomitus lacteus* and *Sphaerotilus natans* were also found.

The contamination of the raw Danube water together with the conditions unfavourable for the existence of the assimilating organisms are shown by the presence of the above mentioned iron- and sulphur bacteria, fungi, etc.

Blue algae *(Cyanophyta)* were found only quite sporadically. We observed only one or two *Oscillatoria* filaments. In the materials collected in February these were present almost constantly.

Two flagellata *(Euglenophyta)* species were found namely *Euglena polymorpha* and *Trachelomonas hispida* came to eye in a few specimens. It was expected that apochromate *Flagellatae* would appear in a greater number under the given conditions, but this was not the case.

The two-furrowed algae *(Pyrrophyta)* exhibited only a single *Peridinium* taxon. The members of this tribe are also otherwise rare habitans of the phytoplancton of the Danube.

Of the yellowish green algae *(Xanthophyceae)* the *Tribonema*, of the yellowish brown algae *(Chrysophyceae)* the *Mallomonas* were identified in one or two specimens.

Diatomeae *(Bacillariophyceae)* were, as a contrast represented with 60 taxons. Their specific occurence has been but sporadical. The most constant taxon was *Stephanodiscus hantzschii* which appeared in almost every sample. Generally only two three specimens per ml were found while its maximal number amounted at the end of January to 5 ind./ml. *Navicula gracilis* and *N. radiosa* are still to be reported, which are in January and February scarse in number, at the end of March, however, their quantity rose to a value of 4 ind./ml. Of more frequent occurrence are with sparse individual number *Cymatopleura solea, Cymbella ventricosa, Diatoma elongatum, D. vulgare, Melosira varians, Nitzschia kützingiana, N. linearis, N. sigmoidea, Synedra acus* and *S. ulna*. Among the algae though in partly disorganised state. Diatomeae are the most characteristic members of the phytoplancton of the ice bound Danube.

The green algae *(Chlorophyta)* are represented also under normal conditions in the winter plancton with a low species- and individual number. Their presence is in the ice covered Danube insignificant. Merely one or two *Scenedesmus* and *Ankistrodesmus* specimen showed their appearance, and even these in a necrotic state.

In the deterioration of the quality of the raw winter Danube water the algal deficiency played to all probability a very important part.

Qualitative and quantitative analysis of the microorganisms of the raw Danube water.

A) The number of the species summarized according to tribes on monthly succession:

Tribes	*January*	*February*	*March*
Schizomycophyta and Mycophyta	4	2	7
Cyanophyta	1	1	1
Euglenophyta	—	1	1
Chrysophyta	42	36	33
Pyrrophyta	1	—	—
Chlorophyta	3	2	1
Altogether:	51	42	43

B) The limit values of the occurring individuals in ind./ml rates in monthly succession:

Tribes	*January*	*February*	*March*
Schizomycophyta and Mycophyta	2–7	1–7	5–15
Cyanophyta	0–1	—	—
Euglenophyta	—	—	—
Chrysophyta	5–17	2–5	4–88
Pyrrophyta	—	—	—
Chlorophyta	0–1	—	—

We recorded above the qualitative features of the chemical and microbiological state of the Danube water under ice cover in the extremely cold winter of the year 1962/1963. The special condition of the quantitative and qualitative state of the microorganisms from the standpoint of the water supply is shown by the comparison of the results of the examinations with the earlier ones.

We refer to the study of Szemes, G., Bozzay, E. and Bánáti, M.: 1963a, b.

In the determination of the phytoplancton we consulted the following works: Rabenhorst: Kryptogamen-Flora, Pascher: Die Süsswasser-Flora, Huber – Pestalozzi. Das Phytoplankton des Süsswassers, moreover the studies of Hustedt (1957, 1959), of Proshkina – Lavrenko (1951, 1955) and of Cleve – Euler (1951 – 1955).

The present state of the Hungarian Danube investigations is reported in the studies of Dudich (1960, 1961). Concerning to the cryptogamic plants of the Hungarian Danube and their literature we refer to the contributions of Szemes (1960, 1961).

РЕЗЮМЕ

Дунай и его притоки были покрыты в зимний период 1963 года в течение более длительного времени непрерывным ледяным покрытием и толстым снежным покровом. Это обстоятельство во многих отношениях влияло на жизнь реки.

1. Оно препятствовало естественной аэрации воды, прием кислорода из воздуха был сильно ограничен, вследствие которого содержание растворенного в воде кислорода уменьшено. Минимум измерен в феврале и был равен 46 проц.

2. Тольстый ледяной покров препятсвтовал проникновению солнечного света в воду. Число ассимилирующих растительных микроорганизмов стало черзвычайно низким. Чрезмерное снижение ассимиляции способствовало снижению содержания кислорода в воде.

3. Вследствие лелдяного покрова удаление продуктов разложения органических веществ в воде стало невозможным. Даже и вследствие повышения растворимости в связи с низкой температурой увеличилось накопление вредных газообразных веществ.

4. Следует подчеркнуть, что содержание окисляемых органических веществ в воде в зимний период вообще имело высокие занчения. И это – вместе с хлоридными ионами – указывает на увеличение растворенных загрязнений воды.

5. Длительная низкая температура, недостаток света, все растущее содержание относительного количества загрязненной воды, и недостаточная аэрация совместно препятствовали химическим и биологическим процессам, способствующим самоочищению воды. Минерализация загрязненных вод, спущенных в Дунай, не могла иметь место в обычной и желательной мере.

6. В воде Дуная стал чувствоваться непрятный вкус, дохлый, напоминающий на химические агенты. В нашем снабжении с питьевой водой это проявилось прежде всего в случае искусственно очищенных вод, но после этого, даже и в случае воды, профильтрованной прибрежными колодцами.

Ухудшение вкуса и запаха устранялось лишь после удаления ледяного покрова с повышением уровня воды.

После удаления ледяного покрова во вторую половину месяца марта восстановлено обычное химическое и биологическое состояние Дуная.

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